ÉTUDE SUR LA SANTÉ DANS LA RÉGION DE

Belledune

AREA HEALTH STUDY

Belledune • Petit-Rocher • Pointe-Verte

Appendix AB - Air Quality Modeling

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Appendix AB Air Quality Modeling

B1.0 Air Dispersion Modeling Overview

Air dispersion models are routinely used to predict the behaviour of chemicals released to the air. Air dispersion models are used for many purposes including for example, to determine whether or not the air emissions from a source are in compliance with regulatory air quality guidelines and criteria, to provide input to engineering design studies, and to provide input to environmental studies and risk assessments.

In this analysis, an air dispersion model, CALMET/CALPUFF, was used to predict both spatial and temporal patterns of chemical levels in the air needed for the human health risk assessment (HHRA). Available local air quality monitoring data were used to benchmark the predicted air concentrations and to provide a "reasonableness" or "reality check" on the predictions.

B1.1 Physical Aspects

In simple terms, air dispersion models use mathematical equations to simulate the atmospheric processes that transport and diffuse air emissions from a source of pollution. In order to apply these models, a number of factors which affect how the air emissions are dispersed in the atmosphere are needed, some of these are:

- The characteristics of the air emission source itself. For example, the air emissions from an elevated point source such as a smelter stack or a power plant stack will behave differently in the atmosphere from those released near to the ground or captured in the wake of a large building. In addition, factors such as height of a stack, exit temperature and exit velocity can also play an important role in how the air emissions are dispersed.

- The meteorological conditions at the time of a release are clearly important to the air dispersion process. Some of the key considerations here include:

  - Wind speed - chemical concentrations decrease with increasing wind speed as a result of dilution. In addition, wind speed increases with height as surface friction decreases. This change of wind speed with height is especially important for elevated sources.

  - Wind direction - dictates the direction from the source that a pollutant will travel. (By convention, wind direction is given as the direction <u>from</u> which the wind blows.)

- The stability of the atmosphere - is a function of the vertical temperature structure of the atmosphere and is a measure of the atmosphere's ability to mix pollutants. Atmospheric stabilities range from unstable -category A to stable F. Neutral D stability is typically the most prevalent stability.

- The height of the mixing layer is the vertical height through which air emissions will mix and provides a measure of estimating the volume of air available for mixing with air emissions. This is important to characterize because a low mixing height can trap emissions and cause elevated ground-level pollutant concentrations.

- Topography and land-use are also important considerations, for example:

  - Land-sea interactions such as exist at Belledune can have a large effect on local meteorological conditions and hence on the air dispersion processes for tall sources. During stable, on-shore wind flow, differences in the heat capacity, the surface roughness and moisture in the air between the water and the land, can cause a boundary layer to form. This is known as the Thermal Internal Boundary Layer (TIBL). TIBL can have significant effects on plume dispersion. When a plume crosses the TIBL a downwash condition can occur, resulting in locally elevated ground level concentrations.

  - The presence of topographic relief can be important and needs to be considered.

  - Mechanical turbulence arising from the interaction of the winds with obstacles on the ground (e.g., buildings, trees etc.) depends on the roughness of the surface and the wind speed. Thus, land-use and ground cover can be important considerations. For example, the air flowing over a forest is more likely than not to be more turbulent than air flowing over a farmer's field or a grassland.

B1.2 Air Dispersion Model

CALPUFF is a non-steady-state air quality modeling system which consists of three component sub-systems: 1) a meteorological modeling package (CALMET) with both diagnostic and prognostic wind field generators; 2) a Gaussian puff dispersion model (CALPUFF) with chemical removal, wet and dry deposition, complex terrain algorithms, building downwash, plume fumigation, and other effects; and, 3) post-processing programs (CALPOST) to process the output of meteorological data, concentration and deposition fluxes. (Scire, J.S. *et al.* 2000a, b; U.S. EPA 1995b)

The CALPUFF Modeling System was designed to address the following specifications:

- the capability to treat time-varying point and area sources;
- suitability for modeling domains from tens of metres to hundreds of kilometres from a source;
- predictions for averaging times ranging from one-hour to annual;
- applicability to model inert pollutants and those subject to linear removal and chemical conversion mechanisms; and,
- applicability to rough or complex terrain.

The CALMET Model is a meteorological model which includes a diagnostic wind field generator containing objective analysis and parameterized treatments of slope flows, kinematic terrain effects, terrain blocking effects, a divergence minimization procedure, and a micrometeorological model for over land and over water boundary layers. CALMET develops hourly wind and temperature fields on a three-dimensional gridded modeling domain which incorporates the effects of terrain on wind flow. Associated two-dimensional fields such as mixing heights, surface characteristics and dispersion properties are also included in CALMET. The three-dimensional (3-D) wind field can be developed by CALMET using observations from several meteorological monitoring stations in the vicinity of the emission source. Alternatively, if there are no suitable surface monitoring data available for the area, CALMET has the option to import prognostic wind field data produced by the MM5/MM4 (Penn State/NCAR Mesoscale Model) as well as from the ETA and NMM models. These models are state-of-the-science meso-scale forecasting models developed by National Center for Environmental Prediction (NCEP). See http://wwwt.ncep.noaa.gov/.

CALPUFF is a transport and dispersion model that advects a discrete number of packets of pollutant material (i.e., "puffs") emitted from sources to represent a continuous plume, simulating dispersion and transformation processes along the way. Temporal and spatial variations in the meteorological fields derived from CALMET are explicitly incorporated in the resulting distribution of puffs throughout the simulation period. Alternatively, CALPUFF can be run with meteorological data from a single monitoring station as with other commonly available regulatory Gaussian plume dispersion models although this does not utilize the full capability of the CALPUFF Model.

In a situation in which wind direction would carry a plume from a source towards a receptor on a hill, the use of the 3-D wind field in CALPUFF allows the determination of whether that puff release will be carried over or around the hill, while a standard Gaussian plume model, using wind direction derived from a single meteorological monitoring site, would predict the flow to be over the hill in all cases.

The original development of the CALMET/CALPUFF models was sponsored by the California Air Resources Board (CARB) and is supported by the U.S. Environmental

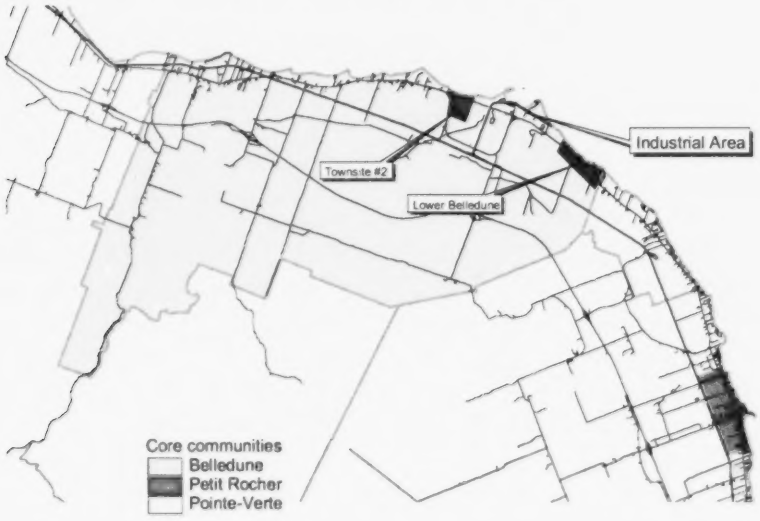
Protection Agency (U.S. EPA). Both the CALMET and CALPUFF models have been enhanced as part of work conducted for the Interagency Workgroup on Air Quality Modeling (IWAQM), the U.S. EPA, the U.S. Forest Service, the U.S. National Park Service, the U.S. Fish and Wildlife Service, and private industry in the United States and abroad. In June 2000, the U.S. EPA proposed including the CALPUFF modeling system as a Guideline model for regulatory applications involving long range transport and on a case-by-case basis for near-field applications where non-steady-state effects (i.e., situations where factors such as spatial variability in meteorological fields, calm winds, fumigation, re-circulation or stagnation, and terrain or coastal effects) may be important. The use of CALPUFF for this application is, according to the proposed U.S. EPA Guideline, an alternative refined model use (U.S.EPA 2003a). CALMET/CALPUFF model is well suited for application in a setting such as Belldune with multiple sources and complex meteorology.

B2.0 Study Area And Time Frame

B2.1 Study Area

For the purposes of the air dispersion analysis, the study area was centered on the air emissions sources located in the Belledune industrial area and generally extends from Petit-Rocher in the east to the western limits of the community of Belledune to the west as shown below in Figure B2.1.

Figure B2.1 Core HHRA Study Area



B2.2 Time Frames

Potential health risks arising from exposure to the COPC are due to chronic (long-term, exposures) rather than acute exposures and thus, annual mean or long-term average air concentrations were estimated throughout the study area.

The 2003 period provides the best available information on emissions, meteorological conditions and environmental monitoring data and thus forms the basis for estimating air dispersion factors and for "benchmarking" the model predictions by comparison to measured values.

For prior time periods, beginning in 1966, air concentrations at the various receptor locations were estimated using the air dispersion factors developed for 2003. DELG indicated that the 2003 Hi-vol measurements were not valid and thus benchmarking of

the model was done using annual emissions from 2000 to 2002, meteorology from 2003 and measured data from 2000-2002. The use of multiple years reduces the effect of uncertainty in individual year emissions. The HHRA provides a discussion of the time periods considered. It was assumed that the physical characteristics of the sources (e.g. stack height or flow rates) are similar for all time frames. The average emission rate during earlier time periods was multiplied by the unit air dispersion factor based on 2003 meteorology. This assumption is likely to overestimate air concentrations from stacks in the earlier time frames since the unit air dispersion factors were developed for stacks with the current configuration with air emission controls which are likely to underestimate thermal plume rise that would have occurred in the past before control devices were installed.

B3.0 Sources in the Belledune Industrial Area

The sources considered for air dispersion modeling were those industries located within the Belledune industrial area. Smaller industrial sources (e.g. seafood processing) located within the general study area or relatively larger industries located outside the generally study area boundary such as NB Power's Generating Station in Dalhousie or the paper mill in Bathurst were not included in this assessment.

The Port of Belledune industries began operation starting with the lead smelter in 1966 with other industries beginning after that time. Table B3.1 summarizes the relevant industrial facilities in the Belledune Industrial area. (See Figure B3.1 for the locations of these industries in the Belledune Industrial Area). SO_x and NO_x emissions from the Canadian Gypsum Company and Chaleur Sawmill were not included because the Noranda and New Brunswick Power sources are larger and the dominant sources.

Table B3.1 Air Emission Sources in the Belledune Industrial Area

Industry	Activity	COPC Identified	Time Period
Noranda Lead /Zinc Smelter	Smelting of lead and zinc concentrates	SO_x, NO_x, arsenic, cadmium, chromium, lead, thallium, zinc, dioxins and furans, mercury	1966-present
NB Power	Electrical power generation using coal and petroleum coke	SO_x, NO_x, arsenic, cadmium, chromium, lead, thallium, zinc, dioxins and furans, mercury	1997-present
Battery Recycling	Lead acid battery recycling generating lead concentrate	arsenic, cadmium, chromium, lead, thallium, zinc	1996-present
Canadian Gypsum Company	Production of gypsum from NB Power by-product	arsenic, cadmium, chromium, lead, thallium, zinc	1996-present

Figure B3.1 Location of Industries in the Belledune Industrial Area

B4.0 Data for Meteorological Analysis

B4.1 Meteorological Data Sources

B4.1.1 Surface and Upper Air Meteorological Data

Dispersion patterns are influenced by surface meteorology and by meteorological conditions above the surface. Figure B4.1 shows the locations of surface and upper air meteorological stations in the vicinity of the study area.

There are only two meteorological stations in close proximity to the meteorological modeling domain, namely Charlo Airport and Bathurst Airport. For most of 2003, both of these stations reported only day-time observations (from 7:00 AM to 9:00 PM) and night-time observations are missing. Since November 2003, the Charlo Airport switched to an automated meteorological station and, hence, 24-hour meteorological data are available for this station from that time. A recent air dispersion study (JWEL 2003) used data from the Gaspe Airport for dispersion analysis noting that Environment Canada considered the Gaspe data were suitable for that study (Environment Canada 2004).

In addition, meteorological observations are carried out on-site, at the Noranda Smelter site recording wind speed, wind direction and temperature on an hourly basis.

Wind roses summarize the frequency of wind and the wind speed by direction. A comparison of wind roses for Charlo, Gaspe and the Noranda site station shown in Figure B4.2 indicates that the wind blows most frequently from the west with easterly winds being the next most frequent. Winds from the north or south are relatively infrequent. While the wind direction frequencies are relatively similar for the three stations, there is some tendency for an increased northerly component at the Gaspe airport. In addition, while the wind roses for the three stations show similar average wind speeds for winds from the west and east directions; the Gaspe station tends to show higher wind speeds for southerly winds than do the other more nearby stations.

Figure B4.3 shows a comparison between wind roses for the period (1999-2003) and 2003 for the Noranda onsite meteorological station. There is little difference in either wind direction or speed between the 2003 observations and the most recent five-year period. On this basis, meteorological conditions for 2003 are considered representative of long-term (tens of years) meteorological conditions in the study area.

Figure B4.1 Surface and Upper Air Meteorological Stations

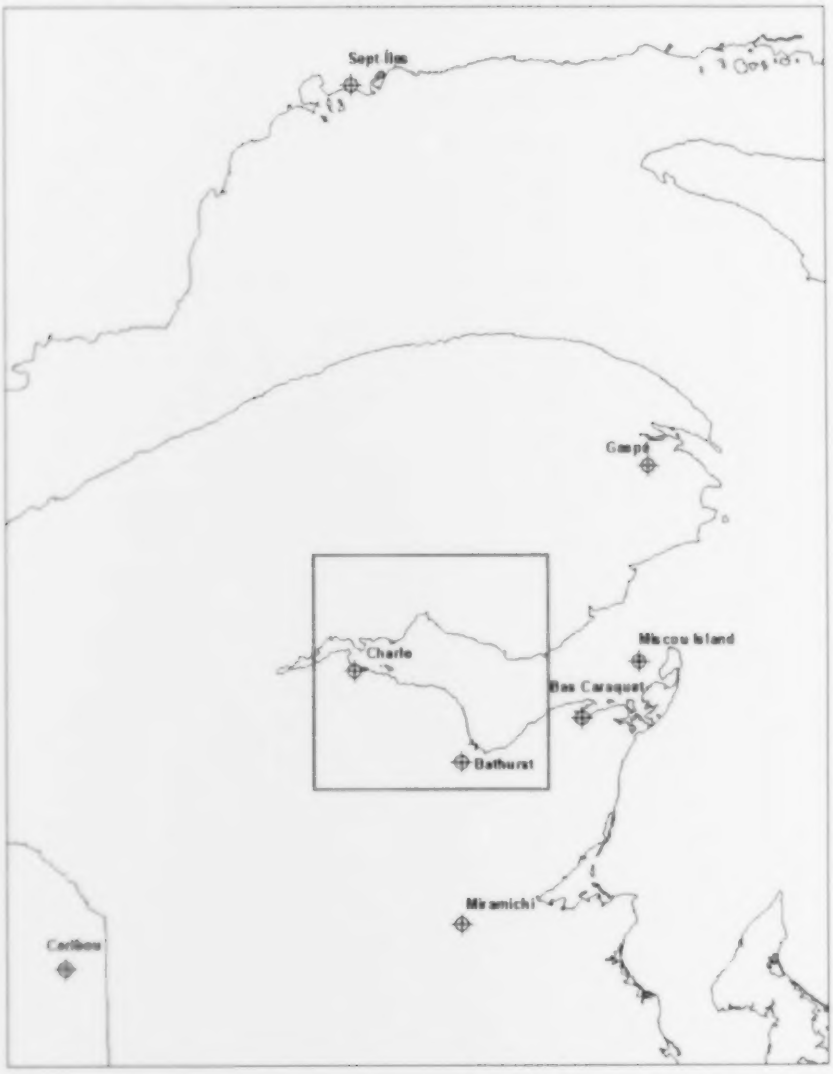


Figure B4.2 Wind Roses for Charlo (1966-1980), Gaspe (1965-1980) and Noranda (1999-2003) Stations

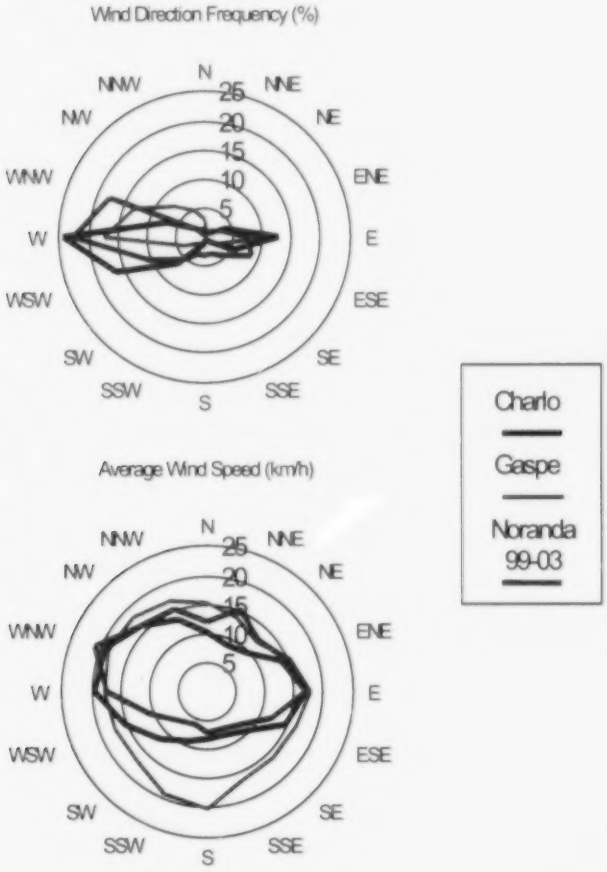
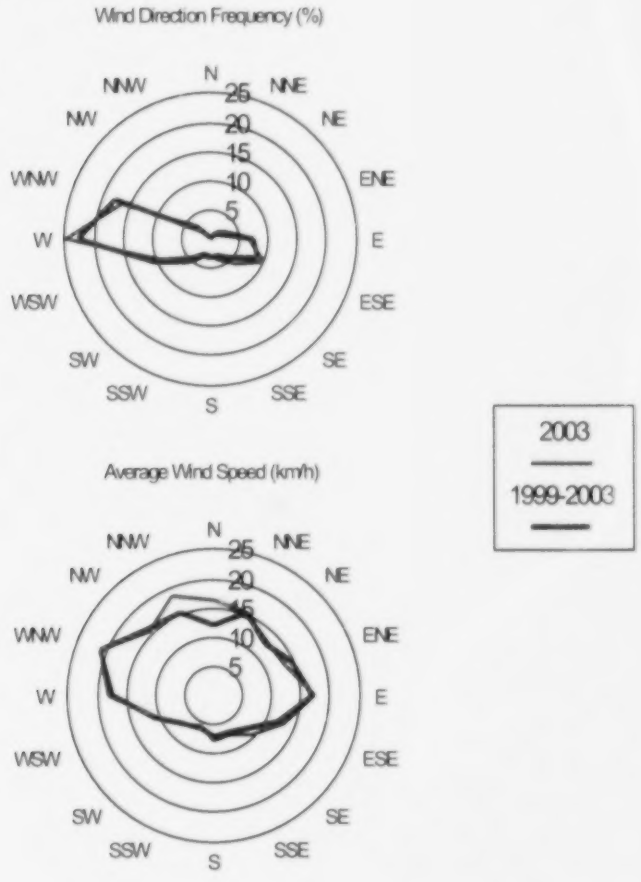


Figure B4.3 Wind Rose Comparison for the Period 1999-2003 Versus 2003 – Noranda Station



B4.1.2 Meteorological Data Used for Dispersion Modeling

Meteorological data for the reference year 2003 was used in CALMET to develop the meteorological data fields used to drive the CALPUFF dispersion model. . CALMET uses all available meteorological data within a defined modeling domain to compute gridded 3-D wind fields. As a minimum, CALMET requires data from one surface station and one upper air (sounding) station. In addition, CALMET also requires that at least two upper air soundings be available daily, and that there is wind and temperature data at the bottom and top layer of the modeling domain.

The meteorological domain is quite large and the local monitoring data is limited. In addition, sea-breeze and terrain effects can be expected in the study area. Thus, the CALMET meteorological processor was coupled to the meso-scale model NMM. The NMM Forecast Model (version 041011 (Janjic *et al.* 2003, 2004) was used to collect and format initial and boundary conditions from NCEP's Eta-12 on a 12 km x 12

km spatial resolution and 39 vertical pressure levels. (The NMM system as implemented in the SENES FReSH4 (version 04101) was used for this purpose.) to produce 2 km by 2 km forecasting fields which were then used to drive the CALMET model on 200 m by 200m grid spacing over the entire modeling domain.

In turn, CALMET was used to develop the reference 2003 year data set of hourly 3-D wind fields (consisting of 7 vertical layers) for use by the CALPUFF dispersion model. It was determined that the 2003 meteorological data set was representative of the time-year period from 1999 to 2003. The pattern of rising vertical layers follows the guidance from the CALMET user's manual in terms of gradually increasing layer depth with height. The CALMET layer heights used are shown in Table B4.1. The CALMET model was run to develop meteorological input for the CALPUFF modeling domain (to ensure that no edge effects were created, the CALMET model was run for a domain greater than the desired modeling domain for CALPUFF) of 65 km by 50 km with a grid spacing of 200 m.

Table B4.1 CALMET Wind Field Layer Heights

Top Height of Layer (m)	Vertical Height of Layer (m)	Notes
20	20	10-metre meteorology
75	55	
100	25	
200	100	
500	300	
1500	1000	
3300	1800	

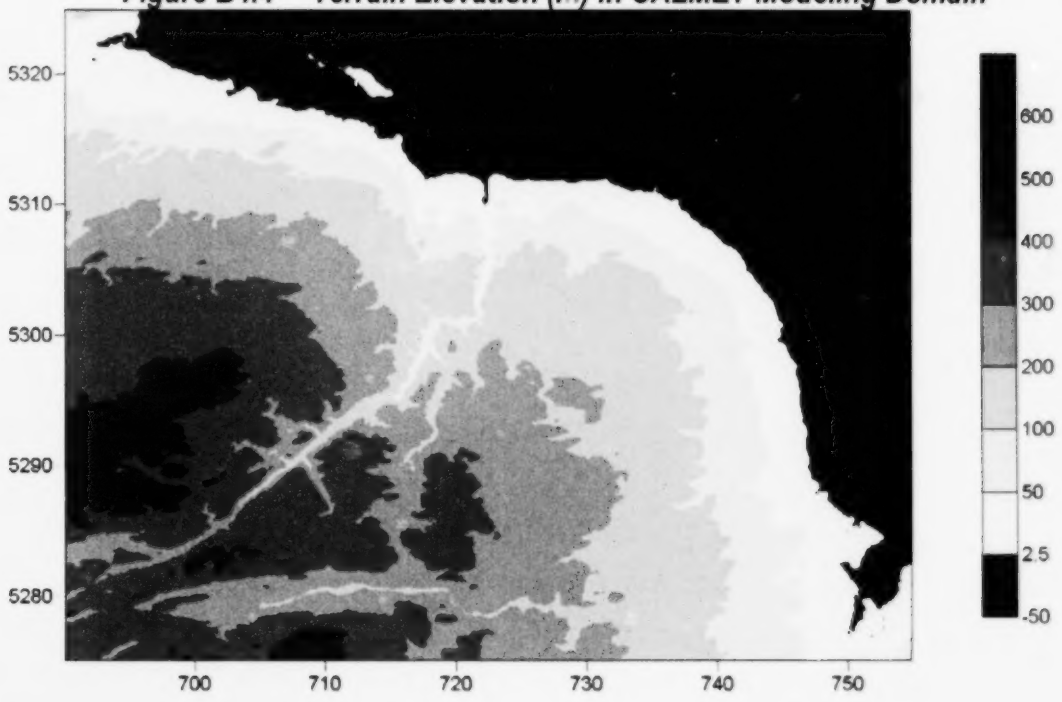
The mixing heights in "*A Mixing Heights Study for North America (1987 –1991)*" (Young and Radonjic 1997) from all upper air stations in modeling domain were reviewed to ensure that the top of the grid is well above the climatological mixing heights which are in the range of 800-1200 m.

B4.1.2.1 Terrain Data

The terrain (i.e. elevation) data used in the CALMET model simulation is from the US Geological Service (USGS) and is based on satellite observations (NASA 2004). The data set is known as the Shuttle RADAR Topography Mission (SRTM). The data are available as SRTM1 for 1 arc second horizontal resolution and STRM3 with 3 arc second resolution (~ 90m). The latter data set with 90 m horizontal resolution was used in this study. The data were downloaded from ftp://edcsgs9.cr.usgs.gov/pub/data/strm.

Figure B4.4 illustrates the CALMET- processed terrain data for the CALPUFF modeling domain.

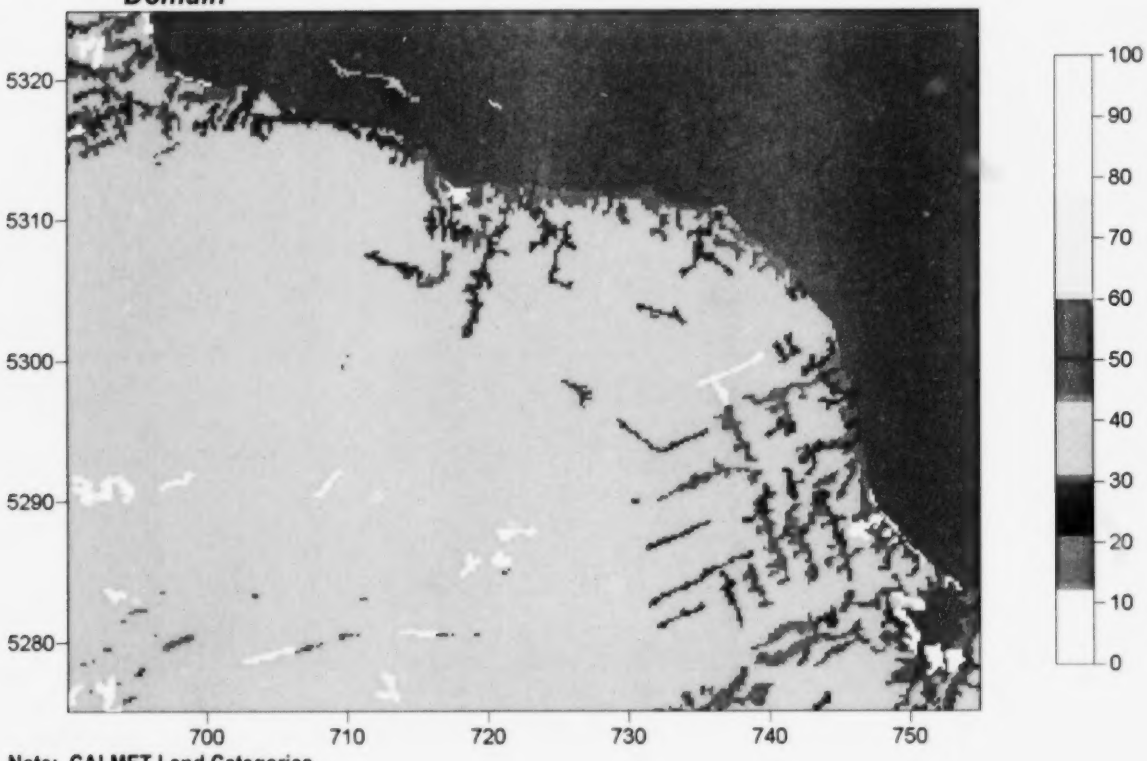
Figure B4.4 Terrain Elevation (m) in CALMET Modeling Domain



B4.1.2.2 Land Use Data

Land use data were obtained from Geomatics Canada. Figure B4.5 presents land-use data processed through CALMET for the CALPUFF modeling domain.

Figure B4.5 Processed Land use data for CALMET Modeling Domain

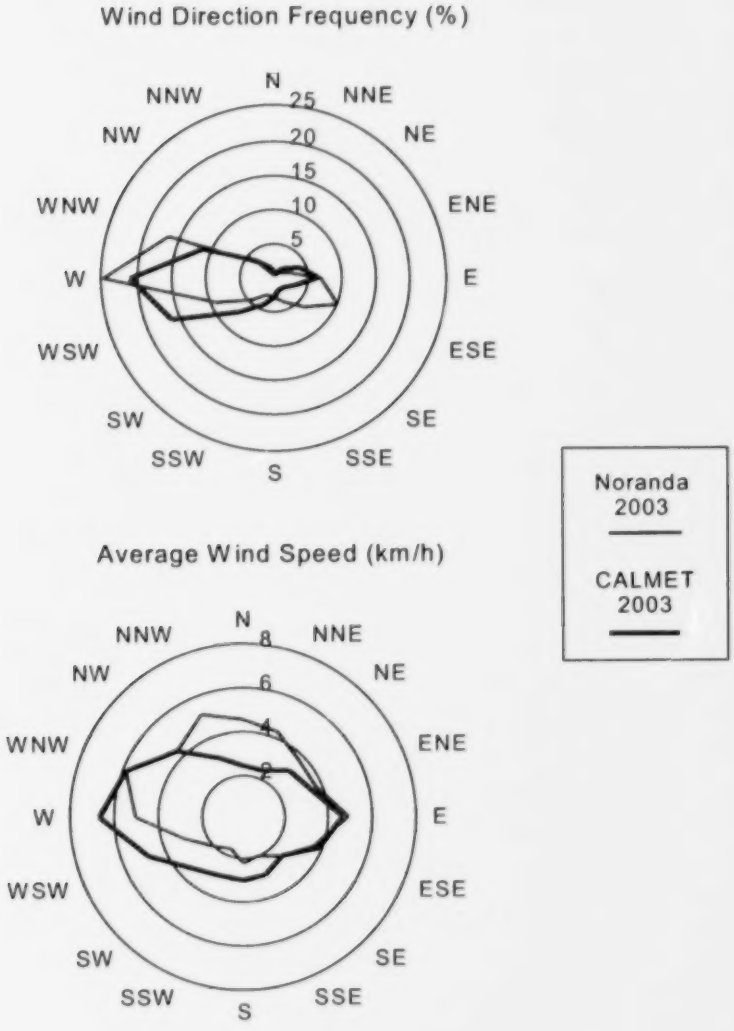


Note: CALMET Land Categories

10	Urban
20	Agricultural – Unirrigated
-20	Agricultural – Unirrigated
30	Rangeland
40	Forest Land
50	Water
51	Small Water Body
55	Large Water Body
60	Wet Land
61	Forested Wet Land
62	Non-Forested Wet Land
70	Barren Land
80	Tundra
90	Perrennial Snow or Ice

The terrain, and land use data were processed with CALMET 3-D wind fields. A comparison of the CALMET generated wind rose and the Noranda site wind rose for 2003 is illustrated in Figure B4.6. The wind rose comparison illustrates good agreement, and supports the use of the CALMET generated wind fields in the CALPUFF dispersion modeling.

Figure B4.6 Wind Rose Noranda 2003 vs. CALMET 2003



B4.3 Uncertainty and Data Gaps

Data processed using CALMET was found to be suitable for air dispersion modeling in the modeling domain. Also, based on a comparison between 2003 and the period from 1999 to 2003 as well as comparisons with historic data records from Charlo and Gaspe, the data from 2003 was determined to be representative of earlier timeframes.

B5.0 Emissions Inventory

The emissions inventory provides information on the type of chemicals released to the atmosphere, the quantity of each chemical and the conditions of release, which govern the manner in which the chemical will be dispersed under various meteorological conditions. These are required inputs for air dispersion modeling.

The most accurate inventory is prepared from information provided by the facilities themselves. They include stationary point source data that gives not only the quantity of chemical but also release data such as stack diameter, temperature, exit velocity and height of chemical release.

Emissions inventories include information on a various types of sources (like a chimney or stack), area sources (like a storage pile) and fugitive sources (like roof vents or leaking pipes). Emission data includes the rate of release (e.g. grams per second) from the source, the chemical composition and the physical form (e.g. gas or particle). A very important consideration is that the release rate can vary over time with changes in production rate or changes in process technology.

Where emissions data were not available directly from the facilities, emissions data were generated from the Federal inventories or based on the production rate and standard emission factors. However, use of emission factors and inventory data was based on less detail and therefore, less certain than using site specific data.

B5.1 Noranda Smelter

B5.1.1 Point Source Emissions

Noranda began operations in 1966, and was originally named Brunswick Smelting Limited. The facility was operated by a subsidiary of Brunswick Smelting known as East Coast Smelting and Chemical Company Limited (P. Deveau, Personal Communication, 2005). Since that time, the facility has undergone several process and/or emissions control changes. A summary of plant operations as derived from financial reports (Excel file GGI 1162) provided information on earlier emission rates and major changes in processes. Process changes typically result in reduction of emissions or changes in the physical characteristics of the emissions. For example, typical emission rates of lead in the late 1980s were approximately two or three times higher than emission rates during the late 1990s. Some key dates relative to process changes are provided in Table B5.1.

Table B5.1 Key Dates for Process/Emissions Changes at Noranda Smelter

Date	Activity
1966	Start of operations
1972/1973	Central baghouse commissioned and conversion from ISF to Pb furnace
1977	Blast furnace baghouse commissioned
1979	Major plant roadways paved
1992	New electrostatic hot gas precipitator, silver and SRF baghouses commissioned, Pb baghouse de-commissioned
1996	New acid plant pre-heater and concentrate facility commissioned

Noranda has provided a summary of annual emissions stack and by year from 1986 through 2003 for a broad range of chemicals including many of the COPCs. This information includes stack parameters (e.g. height, flow velocity) (Excel file GGI 1025). Table B5.2 summarizes total emissions in 1986 and 2002 along with the ratio between emissions in the two years. Concentrations of many of the metals have decreased substantially. For example, the lead emissions in 2002 are 1/10th of the emissions in 1986. Total releases of lead, arsenic and cadmium were also provided from 1975 through 1994 (Brunswick Smelting and Fertilizer 1995). Lead releases prior to 1975 were reported as 4,890 lbs/day (2218 kg/d). Assuming this occurred for 365 days per year, the annual emission of lead would have been about 800,000 kg or about 10 times the rate in 1986 and about 100 times the amount released in 2003.

Table B5.2 Noranda Emissions to Air (1986 and 2002)

Chemical	Units	Ratio of 1986/2002 Emissions	1986 Emissions	2002 Emissions
NOx	(Tonnes/yr)			28
SO2	(Tonnes/yr)	2.0	17000	8300
As	(kg/yr)	1.6	5300	3300
Cd	(kg/yr)	4.0	3400	860
Cr	(kg/yr)			33
Hg	(kg/yr)			68
Pb	(kg/yr)	10	86000	8600
Zn	(kg/yr)	3.6	9100	2500

There have been several studies which have evaluated emissions from the Noranda Smelter, over different time frames. An ambient stack sampling program was conducted in 1976 (*Belledune Survey Report* ; New Brunswick Dept. of the Environment 1977) of suspended particulates, SO_2, As and Pb. Also, the Environmental Impact Assessment Report prepared for the Belledune Thermal Generating Station in 1989 (Washburn & Gillis Associates Limited 1989), summarized stack characteristics and emissions data for the three primary sources at the Noranda Smelter for SO_2, NO_x and particulate.

Release rates from 2000 to 2003 were used to calculate the relative contribution of each stack to total emissions for that time period. These relative contributions were used to estimate the release rate by individual stack during earlier time periods. This assumption is likely to overestimate air concentrations from stacks in the earlier time frames. The unit air dispersion factors were developed for stacks with the current configuration with air emission controls which are likely to underestimate thermal plume rise that would have occurred in the past before control devices were installed. The COPC emissions assigned to each source for each time frame are summarized in Section B5.5.

B5.1.2 Fugitive Emissions

No information on fugitive emissions from the Noranda facility was available. A fugitive area source covering the Noranda building was modeled as 10% of total emissions from the point sources was applied to this 14.2 ha area source. This assumption is based on general experience with other similar industrial sources and was used in the absence of site-specific data. The COPC emissions assigned to each source for each time frame are summarized in Section B5.5.

B5.2 NB Power

B5.2.1 Point Sources

NB Power began operations in 1993. The National Pollutant Release Inventory (NPRI). NPRI is a Federal database which is publicly available http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm. Facilities with reportable emissions submit summaries of their emissions data to NPRI on an annual basis. This program was initiated in 1994. NPRI data is available since 1997 through 2002 for NB Power. Table B5.3 summarizes emissions for COPC for the most recent year of available data on the NPRI namely 2002. These emissions were similar to those obtained from DELG. The COPC emissions assigned to each source for each time frame are summarized in Section B5.5.

Table B5.3 NPRI Report 2002 Emissions for NB Power

Substance	Units	NB Power
		2002
Oxides of nitrogen (expressed as NO_2)	tonnes	5700
Sulphur dioxide	tonnes	2100
Arsenic (and its compounds)	tonnes	0.058
Cadmium (and its compounds)	tonnes	0.00033
Chromium (and its compounds)	tonnes	0.012
Dioxins and furans	g TEQ(ET)	0.11
Lead (and its compounds)	tonnes	0.0044
Mercury (and its compounds)	tonnes	0.012
Zinc (and its compounds)	tonnes	0.030

Other data sources used to characterize data for NB Power included:

- An environmental Assessment conducted by New Brunswick Electric Power Commission in 1990 provided estimates of future stack emissions data including SO_2, NO_x, and TSP for the Belledune thermal generating station (TGS). Maximum predicted concentrations for the then proposed Belledune TGS for different scenarios (e.g., due to combined source in the Belledune airshed, with a wet scrubber, etc) are also available (Monenco Consultants Limited 1990a,b) ;
- Estimates, based on Continuous Emission Monitoring (CEM), for NO_x and SO_2 on an hourly basis for the period from 1999 through 2003 (Atmospheric Emissions GGI 1032). For long-term modeling purposes, the differences between CEM and NPRI were considered to be insignificant;
- Additional SO_2 emission data from 1980 to 1989 and projected year 1994 and 2000 SO_2 emission (for different alternatives) are summarized in NB Power SO_2 emission control program document (New Brunswick Power 1988, 1990) Other emission data summarized by NB Power (New Brunswick Power, GGI 1149);
- Approval to operate I-2360 document (New Brunswick Dept. of the Environment 2000) lay out the limit of the rate of release of NO_x and SO_2.

Figure B5.1 NB Power (NPRI Database)

B5.2.2 Fugitive Emissions

Where measured emissions data are not available, the accepted industry approaches, are to estimate the emissions by either a mass balance approach, or based on reported industry/process specific emission factors. Emission factors are generally based on process throughput or production rate.

The primary source of emissions factor information is the U.S.EPA (1995a) document Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary

Point and Area Sources. This document, commonly referred to as AP-42, is updated on a continuous basis. It is available on-line at http://www.epa.gov/ttn/chief/ap42/index.html.

For many industries and process, AP-42 provides industry accepted emission rates. The reported emission factors are generally derived based on measured emissions at actual facilities. AP-42 often also provides the background documentation for the derivation of the emission factor. In many cases, AP-42 provides emission factors for both uncontrolled sources and for sources controlled with specific control equipment (i.e. baghouse or electrostatic precipitator for dust control).

For NB Power, handling of coal (vehicle unloading (AP-42 Section 13.2.4), front-end loader travel (AP-42 Section 13.2.2), front-end loader unloading (AP-42 Section 13.2.4), wind erosion (AP-42 Section 11.2.3 → 1983 Version)) was considered as a fugitive source. The following assumptions were used with the emission factor approach to estimate the total dust emissions, estimated COPC concentrations in the dust were applied to estimate COPC emissions:

- Material moisture content of 5.5%
- Silt content 3.5%
- 1200 tonnes/day delivered by truck (assumed maximum day);
- 12 hour working day;
- Coal transferred by front end loader10 times per day to the feed hopper, each load 10 tonnes, loader travels approximately 20 m;
- Front end loader weight - 48 tonnes;
- Area subject to wind erosion – 8.6 ha – wind erosion conservatively assumed to occur every day.

The COPC concentrations assigned to the dust emissions from this fugitive source are provided in Table B5.4.

The COPC emissions assigned to each source for each time frame are summarized in Section B5.5.

B5.3 Bulk Handling Facility

There is currently no data on emissions, from fugitive or stack sources, for the bulk handling facility. The facility comprises an indoor facility with emission controls and an outdoor petroleum coke (pet coke) storage pile. Releases from the indoor storage area have been considered minimal.

To estimate emissions from this facility, handling of pet coke (vehicle unloading, front-end loader travel, front-end loader unloading, wind erosion) was considered as a

fugitive source. The following assumptions were used with the emission factor approach to estimate the total dust emissions, estimated COPC concentrations in the dust were applied to estimate COPC emissions:

- Material moisture content of 4.8%
- Silt content 3.4%
- 1200 tonnes/day delivered by truck (assumed maximum day);
- 12 hour working day;
- Concentrate transferred by front end loader 10 times per day to the feed hopper, each load 10 tonnes, loader travels approximately 20 m;
- Front end loader weight - 48 tonnes;
- Area subject to wind erosion – 4.0 ha – wind erosion conservatively assumed to occur every day.

The COPC concentrations assigned to the dust emissions from this fugitive source are provided in Table B5.4.

The COPC emissions assigned to each source for each time frame are summarized in Section B5.5.

B5.4 Canadian Gypsum Company (CGC)

Fugitive emissions of both raw and finished gypsum due to material handling (vehicle unloading, front-end loader travel, front-end loader unloading, wind erosion) were considered. The following assumptions were used to estimate the total dust emissions, estimated COPC concentrations in the dust were applied to estimate COPC emissions:

- Material moisture content of 1.2%
- Silt content 19.8%
- 400 tonnes/day delivered by truck (assumed maximum day);
- 12 hour working day;
- Concentrate transferred by front end loader5 times per day to the feed hopper, each load 10 tonnes, loader travels approximately 20 m;
- Front end loader weight - 48 tonnes;
- Two areas subject to wind erosion – 0.5 ha (raw material) and 0.4 ha (finished material) – wind erosion conservatively assumed to occur every day

The COPC concentrations assigned to the dust emissions from this fugitive source are provided in Table B5.4.

Table B5.4 COPC Concentrations (mg/kg) in Fugitive Materials

COPC	NB Power Outside Storage Pile	Bulk Handling Facility Coke Pile	CGC Raw Material	CGC Finished Material
Arsenic	3	1	0.1	0.1
Cadmium	0.4	0.1	0.1	0.1
Chromium	23	2	2	2
Lead	3.3	1.4	1.2	1.2
Mercury	0.05			
Thallium	0.2	0.1	0.1	0.1
Zinc	36	10	4	4

The COPC emissions assigned to each source for each time frame are summarized in Section B5.5.

B5.5 Emission Rates

Source emission rates for each COPC by time period for each industry are presented in Tables B5.5 – B5.8.

Table B5.5 Emission Estimates (g/s) - Current Time Period

Industry	Source ID	Source Type	Arsenic	Cadmium	Chromium	Dioxins and Furans	Lead	Mercury	NO_x	SO_2	Thallium	Zinc
Noranda	Acid Stack	Stack	.	.	.	$1.9x10^{-18}$	.	0.00217	0.75	47.4	.	.
	Furnace BH stack	Stack	0.03935	0.00568	0.00083	$4.8x10^{-17}$	0.03941	.	.	104.2	0.00022	0.01148
	P27	Stack	0.00309	0.00833	0.00065	.	0.05707	.	.	.	0.00195	0.01334
	P50	Stack	0.00017	0.00072	0.00006	.	0.00225	.	.	.	0.00009	0.00104
	P52	Stack	0.00007	0.00031	0.00003	$2.3x10^{-18}$	0.00066	.	.	.	0.00005	0.00031
	SRF Centre	Stack	0.00231	0.00103	0.00019	.	0.01532	.	.	.	0.00022	0.01245
	SRF East	Stack	0.00108	0.00015	0.00008	.	0.00857	.	0.045	.	0.00046	0.00540
	SRF West	Stack	0.00093	0.00071	0.00012	.	0.00341	.	.	.	0.00035	0.00221
	Silver Ref	Stack	0.00053	0.00050	0.00015	.	0.05668	.	0.081	.	0.00005	0.00657
	Sinter BH stack	Stack	0.00295	0.00481	0.00039	$1.1x10^{-17}$	0.12350	.	.	147.8	0.00295	0.01205
	Norenda Bldg	Fugitive	0.00505	0.00222	0.00025	$2.0x10^{-10}$	0.03069	0.00022	.	.	0.00063	0.00649
	NB Pile	Fugitive	$2.6x10^{-6}$	$3.0x10^{-7}$	$1.7x10^{-5}$		$2.6x10^{-6}$	$3.7x10^{-8}$	.	.	$1.5x10^{-7}$	$2.7x10^{-5}$
Bulk Handling Facility	Petk Pile	Fugitive	$4.0x10^{-7}$	$4.6x10^{-8}$	$7.9x10^{-7}$		$7.9x10^{-7}$	.	.	.	$4.6x10^{-8}$	$4.8x10^{-6}$
NB Power	NB Power	Stack	0.00183	0.00001	0.00038	$3.5x10^{-9}$	0.00014	0.00039	181.4	65.5	.	0.00095
CGC	Raw	Fugitive	$5x10^{-8}$	$5x10^{-8}$	$1x10^{-6}$		$7x10^{-7}$	.	.	.	$5.2x10^{-8}$	$2.4x10^{-6}$
	Finished	Fugitive	$4x10^{-8}$	$4x10^{-8}$	$1x10^{-6}$		$6x10^{-7}$	.	.	.	$3.8x10^{-8}$	$2.2x10^{-6}$

Table B5.6 Emission Estimates (g/s) - 1985-1999 Time Period

Industry	Source ID	Source Type	Arsenic	Cadmium	Chromium	Dioxins and Furans	Lead	Mercury	NO_x	SO_2	Thallium	Zinc
Noranda	Acid Stack	Stack	.	.	.	$1.9x10^{-18}$	.	0.00217	0.75	47.4	.	.
	Furnace BH stack	Stack	0.03935	0.00568	0.00083	$4.8x10^{-17}$	0.03941	.	.	104.2	0.00022	0.01148
	P27	Stack	0.00309	0.00833	0.00065	.	0.05707	.	.	.	0.00195	0.01334
	P50	Stack	0.00017	0.00072	0.00006	.	0.00225	.	.	.	0.00009	0.00104
	P52	Stack	0.00007	0.00031	0.00003	$2.3x10^{-18}$	0.00066	.	.	.	0.00005	0.00031
	SRF Centre	Stack	0.00231	0.00103	0.00019	.	0.01532	.	.	.	0.00022	0.01245
	SRF East	Stack	0.00108	0.00015	0.00008	.	0.00857	.	0.045	.	0.00046	0.00540
	SRF West	Stack	0.00093	0.00071	0.00012	.	0.00341	.	.	.	0.00035	0.00221
	Silver Ref	Stack	0.00053	0.00050	0.00015	.	0.05668	.	0.081	.	0.00005	0.00657
	Sinter BH stack	Stack	0.00295	0.00481	0.00039	$1.1x10^{-17}$	0.12350	.	.	147.8	0.00295	0.01205
	Norenda Bldg	Fugitive	0.00505	0.00222	0.00025	$2.0x10^{-10}$	0.03069	0.00022	.	.	0.00063	0.00649
Bulk Handling Facility	Petk Pile	Fugitive	$4.0x10^{-7}$	$4.6x10^{-8}$	$7.9x10^{-7}$		$7.9x10^{-7}$	.	.	.	$4.6x10^{-8}$	$4.8x10^{-6}$
NB Power	NB Power	Stack	0.00183	0.00001	0.00038	$3.5x10^{-9}$	0.00014	0.00039	181.4	65.5	.	0.00095
	NB Pile	Fugitive	$2.6x10^{-6}$	$3.0x10^{-7}$	$1.7x10^{-5}$		$2.6x10^{-6}$	$3.7x10^{-8}$	.	.	$1.5x10^{-7}$	$2.7x10^{-5}$
CGC	Raw	Fugitive	$5.2x10^{-8}$	$5.2x10^{-8}$	$1.2x10^{-6}$		$7.3x10^{-7}$	.	.	.	$5.2x10^{-8}$	$2.4x10^{-6}$
	Finished	Fugitive	$3.8x10^{-8}$	$3.8x10^{-8}$	$1.1x10^{-6}$		$6.5x10^{-7}$	.	.	.	$3.8x10^{-8}$	$2.2x10^{-6}$

Table B5.7 Emission Estimates (g/s) - 1975-1984 Time Period

Industry	Source ID	Source Type	Arsenic	Cadmium	Chromium	Dioxins and Furans	Lead	Mercury	NO_x	SO_2	Thallium	Zinc
Noranda	Acid Stack	Stack	-	-	-	-	-	-	-	-	-	-
	Furnace BH stack	Stack	0.1604	0.0380	-	-	0.2916	-	-	-	-	-
	P27	Stack	0.0126	0.0557	-	-	0.4222	-	-	-	-	-
	P50	Stack	0.0007	0.0048	-	-	0.0167	-	-	-	-	-
	P52	Stack	0.0003	0.0021	-	-	0.0049	-	-	-	-	-
	SRF Centre	Stack	0.0094	0.0069	-	-	0.1134	-	-	-	-	-
	SRF East	Stack	0.0044	0.0010	-	-	0.0634	-	-	-	-	-
	SRF West	Stack	0.0038	0.0047	-	-	0.0253	-	-	-	-	-
	Silver Ref	Stack	0.0022	0.0034	-	-	0.4194	-	-	-	-	-
	Sinter BH stack	Stack	0.0120	0.0322	-	-	0.9138	-	-	-	-	-
	Norenda Bldg	Fugitive	0.0206	0.0149	-	-	0.2270	-	-	-	-	-
Bulk Handling Facility	Petk Pile	Fugitive	4.0×10^{-7}	4.6×10^{-8}	-	-	7.9×10^{-7}	-	-	-	-	-

Table B5.8 Emission Estimates (g/s) - 1967-1974 Time Period

Industry	Source ID	Source Type	Arsenic	Cadmium	Chromium	Dioxins and Furans	Lead	Mercury	NO_x	SO_2	Thallium	Zinc
Noranda	Acid Stack	Stack	-	-	-	-	-	-	-	-	-	-
	Furnace BH stack	Stack	1.0691	0.0913	-	-	1.3477	-	-	-	-	-
	P27	Stack	0.0839	0.1339	-	-	1.9518	-	-	-	-	-
	P50	Stack	0.0047	0.0116	-	-	0.0770	-	-	-	-	-
	P52	Stack	0.0019	0.0050	-	-	0.0225	-	-	-	-	-
	SRF Centre	Stack	0.0627	0.0166	-	-	0.5240	-	-	-	-	-
	SRF East	Stack	0.0294	0.0025	-	-	0.2931	-	-	-	-	-
	SRF West	Stack	0.0253	0.0114	-	-	0.1167	-	-	-	-	-
	Silver Ref	Stack	0.0143	0.0081	-	-	1.9385	-	-	-	-	-
	Sinter BH stack	Stack	0.0802	0.0774	-	-	4.2237	-	-	-	-	-
	Norenda Bldg	Fugitive	0.1371	0.0358	-	-	1.0495	-	-	-	-	-
Bulk Handling Facility	Petk Pile	Fugitive	4.0×10^{-7}	4.6×10^{-8}	-	-	7.9×10^{-7}	-	-	-	-	-

B5.6 Uncertainty and Data Gaps

Recent emission rates from point sources are well known for Noranda Smelter and for NB Power. One consideration that contributes to the uncertainty of historic emissions is that emissions of COPC from the Noranda facility are not necessarily in a directly linear relationship with lead since amounts of these metals as impurities in the lead concentrate can vary over time. Different processes also have different releases of the metals.

The primary data gap is characterization of emissions from fugitive sources. For the Noranda facility, the fugitive emissions were assumed to be 10% of the total point

source emissions. For the other industrial sources, emissions were estimated based on assumed material handling rates.

The uncertainties are addressed through the dispersion modeling calculations described in Section 6.0.

B6.0 CALPUFF MODELING

B6.1 Source Characteristics

The CALPUFF model was applied to (1) discrete receptors and (2) grid points to produce unit dilution factors for each source modeled. Modeled sources and modeled source characteristics for existing conditions are presented in Table B6.1. Point sources from the Chaleur Sawmill and CGI were not considered as Noranda and New Brunswick Power have the dominant point sources.

Table B6.1 Point Source Characteristics – Existing Conditions

Industry	Source ID	Diameter (m)	Height (m)	Temperature (°C)	Flow (m^3/s)	Exit Velocity (m/s)	Elevation (m)
Noranda	Acid Stack	2.29	75.6	80	29	7.04	6.99
	Furnace BH stack	3.96	47.5	54	194.2	15.78	10.55
	P27	1.68	37.2	50	12.64	5.71	9.66
	P50	0.76	33.5	38	2.802	6.18	9.47
	P52	0.56	33.5	35	1.634	6.64	9.27
	SRF Centre	1.68	42.7	55	32.15	14.51	9.44
	SRF East	1.07	31.7	49	8.781	9.77	9.13
	SRF West	1.07	31.7	47	9.487	10.56	9.76
	Silver Ref	1.28	38.9	62	29.85	23.21	9.24
	Sinter BH stack	3.05	47.5	51	145.6	19.94	10.01
NB Power	NB Power	6.86	168	50	517.44	14.01	19.53

B6.2 Dispersion Modeling Approach

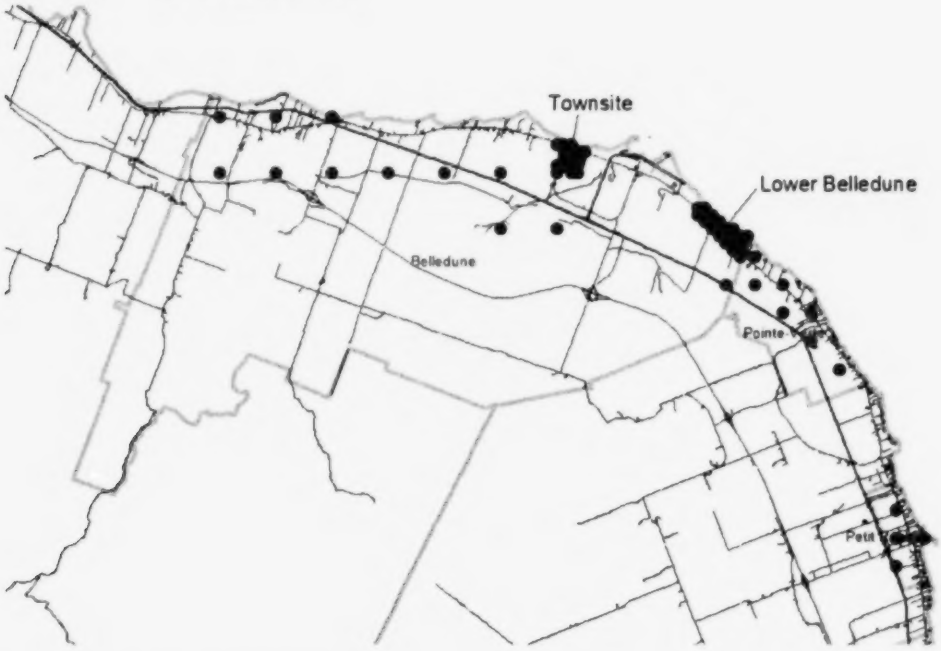
Unit air concentrations were modeled using the CALPUFF model with CALMET meteorological fields and release characteristics. The air dispersion was modeled assuming no plume depletion: this will tend to overestimate predicted concentrations at distance.

B6.2.1 Receptor Grid

Unit air concentration factors and air concentrations were estimated at specified locations extending beyond HHRA study area. The locations included the coordinates of environmental monitoring locations and a series of grid points covering the area. Air dispersion modeling to the monitoring locations was conducted for dispersion model validation and development of empirical relationships between soil concentration and predicted air concentrations. The predicted air concentration for each study area was calculated as the mathematical average of air concentrations at regularly spaced

intervals throughout the study areas. Different grid spacings were used over the study area with the most intensive grid spacing of 250 m grid spacing in the most exposed area. The population density is highest near the shore in these communities; therefore, the mean air concentrations were based on locations near the shore for Belledune and Pointe-Verte. Figure B6.1 shows individual the grid locations used to estimate study area average concentrations and air concentrations were predicted throughout the modeling domain, as illustrated in Figure B6.2.

Figure B6.1 Grid Locations



B6.2.2 Unitized Air Emission Approach

A unitized air emission approach was used for this model exercise. This approach involves applying an emission rate of 1 g/s for each source and modeling each source separately to develop a unit air concentration factor for each receptor. This allows for adjustments to be made to individual source emission rates external to the model.

Unit air concentration factors were summarized on a monthly basis over the study area and at the monitoring locations to provide the annual average unit air concentration factors for each individual source at each receptor locations. These air concentration factors were also used for estimating air concentrations at the same locations in the past by applying the appropriate source emission rate for the time frame.

For the purposes of air dispersion model validation against air monitoring results, hourly unit air concentration factors were retained from the model for each air monitoring location in addition to a small grid of points around each monitoring location to facilitate

small variations in wind direction from the sources to these facilities.

B6.2.2.1 Method

Air concentrations at a location that are attributable to release from a given source are predicted based on multiplying the unit air concentration factor for a given time by the corresponding emission from that source for the corresponding time.

Unit factors for the stack sources are "$\mu g/m^3$ per g/s"
To obtain air concentrations:

$$C = E * F$$

Where:

C = air concentration in $\mu g/m^3$
E = total emission in g/s
F = unit air concentration factor in $\mu g/m^3$ per g/s

Unit factors for fugitive releases are "$\mu g/m^3$ per 1 x 10^{-6} $g/m^2/s$".
To obtain air concentrations:

$$C = (E / A) * F * 1 \times 10^{-6}$$

Where:

C = air concentration in $\mu g/m^3$
E = total emission in g/s
A = areas in m^2 (note E/A give emission rate in $g/m^2/s$)
F = unit air concentration factor in $\mu g/m^3$ per 1 x 10^{-6} $g/m^2/s$ (1 x 10^{-6} cancels the value in the unit concentration factor).

Average unit air concentration factors were calculated for two parts of the year, namely, January to June and July to December.

For most locations, the average unit air concentration factor for the part year was multiplied by the mean release rate to get the contribution to air concentrations attributable to each source. For each location and source, the overall average air concentrations for the part year was determined. Adding up the contributions from each source to the annual average air concentration for each location provides the predicted annual average air concentration attributable to the Belledune industrial area at each locations.

B6.3 Model Validation

For validation of air dispersion predictions against air monitoring measurements, unit air concentration factors were matched against source emissions on an hour-by-hour basis. Air concentrations were calculated for each hour. Hourly predicted air concentrations were compared to hourly SO_2 measurements. Particulate-in-air concentrations are measured over a 24-hour period; therefore, the hourly predicted air

concentrations were calculated over a 24-hour period.

Mean predicted air concentrations and mean measured air concentrations were summarized for the three Hi-vol monitoring sites located within the community. Data from the two Hi-vol locations near the facility were not included in the validation since they are located within the industrial area and do not reflect conditions in the community. For each year, concentrations were first averaged for the January to June period and the July to December period and then these values were averaged for the years 2000 through 2002. Measured values from 2003 were not used in the assessment since that data was considered invalid by New Brunswick DELG (D. Grass, Personal Communication, 2004). Validation of SO_2 was completed for the year 2002 using NPRI reported SO_2 emissions from NB Power and SO_2 emissions reported by Noranda for 2002.

Since background air concentrations of COPC in the study area are not well defined, the mean predicted incremental air concentrations were compared to the total (i.e., incremental plus baseline) measured values at the three high-value stations as shown in Table B6.2 for the five measured COPC and SO_2 at each of the three monitoring locations. Also provided are the combined mean concentrations for the three stations. The ratio between mean measured concentration and mean predicted concentration are provided as an indicator of agreement between predictions and measurements. Ratios less than 1 indicate that the predicted concentrations overestimate the measured concentrations and ratios greater than 1 indicate that the predicted measurements underestimate the measured concentrations.

The initial agreement between predicted and measured values falls with a factor of two for arsenic and cadmium and within a factor of 3 for thallium. Lead concentrations are under-predicted by a factor of five. There will be tendency for the predicted concentrations to under-estimate measured concentrations since baseline contributions of the COPC will be present in the current measured concentrations, but are not incorporated in the model calculations. The general agreement between predicted and measured SO_2 and cadmium concentrations is consistent with the industrial contribution being large at these locations compared to the baseline contribution. Zinc is underestimated by a factor of about 10 compared to measured concentrations. It is likely that the disagreement in zinc concentrations may in part be due to the use of glass fibre filters in the Hi-volume samplers. Noranda indicated (J. Cormier, Personal Communication, 2005) that Noranda switched to quartz fibre filters in 2004 due to high variations of zinc ions and possibly other chemicals. The U.S. EPA (1999) recommends the use of quartz fibre filters because of its low metals content; glass fibres should be corrected to account for high metals content. If no correction for zinc content in the glass fibre filter was made, elevated concentrations of zinc would be measured.

Fugitive releases from the smelter were been set equal to 10% of the stack releases for all COPC except SO_2 and NO_x, There may have been differences in the proportion of

COPC leaving the facility through stacks or through fugitive releases. For example, the proportion of cadmium leaving through fugitive releases may be lower then the proportion of lead leaving through fugitive sources. In that case, predicted lead concentrations would have been underestimated relative to predicted cadmium concentrations.

Table B6.2 Comparison of Measured and Air Dispersion Model Predictions ($\mu g/m^3$) for 2000-2002

Location	Predicted Concentration ($\mu g/m^3$)	Measured Concentration ($\mu g/m^3$)	Ratio
Arsenic			
Combined	0.0058	0.0094	1.61
HI Vol 1	0.0049	0.0086	1.75
HI Vol 2	0.0058	0.0091	1.56
HI Vol 3	0.0068	0.0106	1.56
Cadmium			
Combined	0.0037	0.0042	1.13
HI Vol 1	0.0032	0.0041	1.25
HI Vol 2	0.0033	0.0031	0.94
HI Vol 3	0.0045	0.0053	1.18
Lead			
Combined	0.0372	0.1721	4.63
HI Vol 1	0.0325	0.1908	5.87
HI Vol 2	0.0336	0.1252	3.73
HI Vol 3	0.0455	0.2001	4.40
SO_2			
Combined	6.8509	11.322	1.65
Boulay	5.3757	11.546	2.15
Townsite	7.3648	7.9031	1.07
Chalmers	7.8123	5 14.518	1.86
Thallium			
Combined	0.001	0.0022	2.22
HI Vol 1	0.0009	0.0021	2.46
HI Vol 2	0.0009	0.0019	2.05
HI Vol 3	0.0012	0.0026	2.19
Zinc			
Combined	0.0152	0.1871	12.32
HI Vol 1	0.0105	0.1864	17.68
HI Vol 2	0.0207	0.1691	8.17
HI Vol 3	0.0143	0.2057	14.39

Note: SO_2 validation based on 2002 data.

B6.3.1 Model Accuracy

The U.S.EPA provides the following statements regarding model accuracy (U.S.EPA, 2003b) and the difficulties in validating model predictions using paired short term data:

- These models are recognized to be more accurate at predicting longer time-averaged concentrations than for estimating short-term concentrations at specific

locations;

- The models are also recognized to be reasonably reliable in estimating the magnitude of the highest concentrations occurring sometime, somewhere within an area;
- Poor correlations between paired concentrations at fixed stations may be due to reducible uncertainties in knowledge of the precise plume location and to the unquantified inherent uncertainties. Uncertainty of five to ten degrees in the measured wind direction which transports the plume can result in concentration errors of 20 to 70 percent for a particular time and location, depending on stability and station location. Such uncertainties do not indicate that an estimated concentration does not occur, only that the precise time and location are in doubt;

Longer term validation involves comparing annual, or multi-year, average air concentration data to the average monitored values when available. Such comparisons can be used to estimate the uncertainty in dispersion modeling at unmeasured levels.

B6.3.2 Adjustment Factors

In order to reduce the uncertainty in predicted air concentrations, the relationship between measured and predicted concentrations at the monitoring locations were used to adjust the initial predicted air concentrations. Ratios at individual monitoring locations were similar for the same COPC suggesting that adjustments by direction would be minimal. The initial predicted air concentrations were multiplied by the ratios in Table B6.2 for the combined measurements. For example, the adjusted air concentrations for cadmium were calculated by multiplying the initial air concentrations by 1.13 to estimate the average air concentrations of cadmium used in the HHRA. The same adjustment was used for all locations regardless of distance or direction from the industrial area. Since the adjustment is made on the basis of comparisons of predicted incremental concentrations versus measured total, the adjustment is more likely than not conservative in that it will tend to overestimate the actual contribution of the sources in Belledune industrial facilities.

No adjustment was made for zinc because measured zinc concentrations were high due to the use of glass fibre filters which are known to have a high zinc concentration. Since the zinc concentrations seemed to be reported incorrectly, it was difficult to develop an adjustment factor for zinc.

Monitoring measurements were not available for NO_x, dioxins and furans, chromium and mercury. Predicted air concentrations for these COPC were estimated by multiplying the initial predictions by a factor of 2.4 which is the average factor for arsenic, cadmium, lead and thallium. The adjustment factor for SO_2 was used for NO_x.

B6.4 Dispersion Modeling Results

Tables B6.3 through B6.6 summarizes the mean predicted concentrations by COPC and time period for the five study areas. The summary includes the number of grid points, the mean value for grid points and the maximum predicted concentration at a grid point within the study areas.

The best estimate Environmental Point Concentrations (EPCs) were based on the incremental contribution with adjustments based on comparisons between (average) predictions and monitoring measurements. The best estimate for mean air concentration in a study area was set at the mean concentration after adjustment. Upper bound estimates were set equal to two times the mean predicted concentration. From the two most exposed areas (Townsite #2 and Lower Belledune), the upper bound concentration was set equal to two times the maximum predicted concentration in the area.

B6.4.1 Metals

New Brunswick does not report measured air concentrations for any metals. Ontario Ministry of the Environment (MOE 2003), however, does report measured concentrations for several metals.

B6.4.1.1 Lead

Measured lead concentrations in Ontario are typically approximately 0.01-0.02 $\mu g/m^3$. Health Canada reports an annual average lead concentration in Canada of 0.06 $\mu g/m^3$. However, in several more industrialized communities, (Hamilton, Mississauga), annual average lead concentrations in 2002 were approximately 1.6-1.9 $\mu g/m^3$. The measured (0.12-0.2 $\mu g/m^3$) lead concentrations in the study area are higher than the average lead concentrations in Ontario, but well below the highest measurements in Ontario. The model predictions (Table B6.3) for the communities were adjusted to agree with the measured data (Table B6.2).

Figure B6.2 illustrates the predicted lead concentrations at each receptor location. This figure illustrates the greater density of receptors placed in close proximity to Noranda and in the communities. This figure and the isopleth (Figure B6.3) illustrate that the maximum predicted air concentrations in the immediate vicinity of the Noranda facility are greater than approximately 2 $\mu g/m^3$.

In the 1985-1999 time period, lead concentrations are predicted to have been approximately 3 times greater than the present time period; in the 1975-1984 time period approximately 7 times greater than the present time period and in the 1967-1974 time period approximately 33 times greater than the present time period.

None of the New Brunswick Department of the Environment, Ontario Ministry of the Environment, or Environment Canada have annual criteria for lead.

B6.4.1.2 Arsenic

None of the New Brunswick Department of the Environment, Ontario Ministry of the Environment, or Environment Canada report on arsenic concentrations in air. However, a report prepared by the Ontario Ministry of the Environment (MOE 2004) reports arsenic concentrations measured in PM_{10} in major city centers in Ontario. This report also indicates that the majority of arsenic is bound with the fine particles (PM_{10} and less). The 98th percentile measured values in 2000 were approximately 0.0045 $\mu g/m^3$ in Ottawa and Toronto, and 0.006 $\mu g/m^3$ in Windsor and Hamilton.

On an annual basis, Environment Canada PSL estimates arsenic concentration in air in Canada to be approximately 0.001 $\mu g/m^3$.

California EPA reports a chronic Reference Exposure Level (REL) of 0.03 $\mu g/m^3$ for arsenic.

The measured annual average (Table B6.2 - 0.009 $\mu g/m^3$) and predicted annual average arsenic concentrations in the five communities (Table B6.3 - 0.0003-0.009 $\mu g/m^3$) are similar to or greater than the measurements in the major city centers, but well below the California EPA chronic REL. Figure B6.4 illustrates the predicted annual average arsenic concentrations in the study area for the current time frame. The maximum concentrations (>0.05 $\mu g/m^3$) are in close proximity to the Noranda facility.

In the 1985-1999 time period, arsenic concentrations are predicted to have been approximately 1.7 times greater than the present time period; in the 1975-1984 time period approximately 3.3 times greater than the present time period and in the 1967-1974 time period approximately 22 times greater than the present time period.

B6.4.1.3 Cadmium

Measured cadmium concentrations in Ontario are typically approximately 0.1 $\mu g/m^3$. However, in more industrialized communities, (Hamilton), annual average lead concentrations in 2002 were approximately 0.6 $\mu g/m^3$. The measured (Table B6.2 - 0.004 $\mu g/m^3$) cadmium concentrations in the study area are well below the average cadmium concentrations in Ontario. Environment Canada PSL estimates the annual average Canadian cadmium concentration in air to be approximately 0.001-0.004 $\mu g/m^3$.

The predicted annual average cadmium concentrations (Table B6.3; Figure B6.5) for current conditions show that the highest predicted cadmium concentrations are in the immediate vicinity of the Noranda facility, but that the predicted concentrations are

below measurements made in Ontario in 2002, and within the range of the Canadian average baseline concentrations.

In the 1985-1999 time period, cadmium concentrations are predicted to have been approximately 5 times greater than the present time period; in the 1975-1984 time period approximately 6 times greater than the present time period and in the 1967-1974 time period approximately 15 times greater than the present time period.

B6.4.1.4 Chromium

Measured cadmium concentrations in Ontario (2002) are typically approximately 0.003-0.005 $\mu g/m^3$. However, in more industrialized communities, (Niagara Falls, Hamilton), annual average chromium concentrations can be significantly higher, approximately 0.08-0.9 $\mu g/m^3$. Environment Canada PSL2 estimates the annual average Canadian chromium concentration in air to be approximately 0.003-0.009 $\mu g/m^3$.

The predicted annual average chromium concentrations (Table B6.3) for current conditions show that the highest predicted chromium concentrations (0.009 $\mu g/m^3$) are in the immediate vicinity of the Noranda facility, and that the predicted concentrations are in the vicinity of measurements made in Ontario in 2002, and the Canadian average concentrations.

B6.4.1.5 Dioxins and Furans

The Massachusetts Department of Environmental Protection has developed annual average Allowable Ambient Limits for furans of 0.02 $\mu g/m^3$. The predicted annual average concentrations for current conditions at all locations (Table B6.3; $1x10^{-10}$ and less) are well below this limit.

B6.4.1.6 Mercury, Thallium and Zinc

Similar to lead, cadmium and chromium the maximum predicted concentrations for these constituents are centered around the Noranda facility, and decrease with distance from the facility.

Mercury concentrations in air in Southern Ontario have been reported to be approximately 0.001-0.002 $\mu g/m^3$ (Brook *et. al.* 1997). The predicted mercury concentrations (Table B6.3) are well below these values.

Typical air concentrations of thallium in air are <0.001 $\mu g/m^3$.
(http://www.inchem.org/documents/ehc/ehc/ehc182.htm#SectionNumber:1.4)
The predicted air concentrations in the Belledune area (Table B6.3) are in the range of background levels.

Measured zinc concentrations in Ontario (2002) are typically approximately 0.02 $\mu g/m^3$.

Health Canada (1979) reports an average concentration for zinc in air in Canada of 0.035 μg/m³. However, in more industrialized communities (Hamilton), annual average zinc concentrations can be significantly higher, approximately 0.1 μg/m³. The predicted zinc concentrations (Table B6.3) are within this range.

B6.4.2 Nitrogen Dioxide and Sulphur Dioxide

The EPC Best Estimate model concentrations for current conditions for SO2 range from approximately 1.0 to 11.8 μg/m3 and from approximately 0.3 to 1.2 μg/m3 for NOx Table B6.3. Background concentrations were not added since the model predictions were adjusted to match the measured concentrations (which would include a background contribution).

Average NO2 and SO2 concentrations were measured in Saint John NB in 2002 (Environment Canada 2003) at approximately 10 μg/m3 and 9 μg/m3 respectively. The measured SO2 concentrations in the study area were in the range of 8 to 15 μg/m3 in 2002 (Table B6.2).

The annual average National Air Quality Objective, maximum desirable level, is 30 μg/m3 for sulphur dioxide and 60 μg/m3 for nitrogen dioxide. The analysis illustrates that the measured and predicted NOx and SO2 concentrations (conservatively assuming all predicted NOx concentrations are as NO2 in the environment) are well below applicable air quality criteria. Also, the incremental contribution of NOx and SO2 to the study area is comparable to levels measured in industrialized centers, such as Saint John.

Figure B6.6 illustrates the predicted annual average SO2 concentrations from the dispersion model calculations. The contribution from both Noranda and NB Power are evident in the shape of the isopleths.

Table B6.3 Summary Predicted Mean Air Concentrations (μg/m³) - Current Time Period

Analyte	Exposure Area	Number of Grids	Mean Prediction	Maximum Prediction	EPC Best Estimate	EPC Upper Bound
Arsenic	Belledune	14	0.002	0.007	0.002	0.004
	Lower Belledune	23	0.006	0.014	0.006	0.027
	Petit-Rocher	4	2.90×10^{-4}	3.30×10^{-4}	2.90×10^{-4}	5.80×10^{-4}
	Pointe-Verte	7	0.002	0.003	0.002	0.004
	Townsite	16	0.009	0.013	0.009	0.026
Cadmium	Belledune	14	7.70×10^{-4}	0.002	7.70×10^{-4}	0.002
	Lower Belledune	23	0.003	0.006	0.003	0.011
	Petit-Rocher	4	8.90×10^{-5}	1.00×10^{-4}	8.90×10^{-5}	1.80×10^{-4}
	Pointe-Verte	7	6.40×10^{-4}	0.001	6.40×10^{-4}	0.001
	Townsite	16	0.003	0.004	0.003	0.008
Chromium	Belledune	14	8.20×10^{-4}	0.006	8.20×10^{-4}	0.002

Analyte	Exposure Area	Number of Grids	Mean Prediction	Maximum Prediction	EPC Best Estimate	EPC Upper Bound
	Lower Belledune	23	8.40×10^{-4}	0.002	8.40×10^{-4}	0.003
	Petit-Rocher	4	3.50×10^{-5}	4.10×10^{-5}	3.50×10^{-5}	7.10×10^{-5}
	Pointe-Verte	7	2.50×10^{-4}	4.20×10^{-4}	2.50×10^{-4}	4.90×10^{-4}
	Townsite	16	0.009	0.022	0.009	0.044
Dioxins and Furans	Belledune	14	3.00×10^{-11}	1.00×10^{-10}	3.00×10^{-11}	6.00×10^{-11}
	Lower Belledune	23	1.00×10^{-10}	3.00×10^{-10}	1.00×10^{-10}	5.00×10^{-10}
	Petit-Rocher	4	7.00×10^{-12}	8.00×10^{-12}	7.00×10^{-12}	1.00×10^{-11}
	Pointe-Verte	7	3.00×10^{-11}	6.00×10^{-11}	3.00×10^{-11}	6.00×10^{-11}
	Townsite	16	1.00×10^{-10}	2.00×10^{-10}	1.00×10^{-10}	3.00×10^{-10}
Lead	Belledune	14	0.041	0.132	0.041	0.081
	Lower Belledune	23	0.135	0.289	0.135	0.579
	Petit-Rocher	4	0.005	0.006	0.005	0.01
	Pointe-Verte	7	0.035	0.071	0.035	0.07
	Townsite	16	0.159	0.195	0.159	0.39
Mercury	Belledune	14	5.90×10^{-5}	1.90×10^{-4}	5.90×10^{-5}	1.20×10^{-4}
	Lower Belledune	23	1.90×10^{-4}	3.80×10^{-4}	1.90×10^{-4}	7.70×10^{-4}
	Petit-Rocher	4	7.70×10^{-6}	8.90×10^{-6}	7.70×10^{-6}	1.50×10^{-5}
	Pointe-Verte	7	5.30×10^{-5}	1.00×10^{-4}	5.30×10^{-5}	1.10×10^{-4}
	Townsite	16	2.40×10^{-4}	3.10×10^{-4}	2.40×10^{-4}	6.30×10^{-4}
NO_x	Belledune	14	0.493	1.178	0.493	0.985
	Lower Belledune	23	1.186	1.336	1.186	2.672
	Petit-Rocher	4	0.34	0.371	0.34	0.681
	Pointe-Verte	7	0.853	1.043	0.853	1.706
	Townsite	16	0.337	0.588	0.337	1.175
SO_2	Belledune	14	4.146	11.15	4.146	8.292
	Lower Belledune	23	10.41	14.29	10.41	28.58
	Petit-Rocher	4	1.003	1.145	1.003	2.006
	Pointe-Verte	7	4.71	7.922	4.71	9.42
	Townsite	16	11.78	13.88	11.78	27.76
Thallium	Belledune	4.50×10^{-4}	0.001	4.50×10^{-4}	9.10×10^{-4}	4.50×10^{-4}
	Lower Belledune	0.001	0.003	0.001	0.006	0.001
	Petit-Rocher	5.10×10^{-5}	5.90×10^{-5}	5.10×10^{-5}	1.00×10^{-4}	5.10×10^{-5}
	Pointe-Verte	3.70×10^{-4}	7.40×10^{-4}	3.70×10^{-4}	7.40×10^{-4}	3.70×10^{-4}
	Townsite	0.002	0.002	0.002	0.005	0.002
Zinc	Belledune	0.003	0.016	0.003	0.007	0.003
	Lower Belledune	0.008	0.017	0.008	0.033	0.008
	Petit-Rocher	2.70×10^{-4}	3.20×10^{-4}	2.70×10^{-4}	5.50×10^{-4}	2.70×10^{-4}
	Pointe-Verte	0.002	0.004	0.002	0.004	0.002
	Townsite	0.022	0.044	0.022	0.087	0.022

Table B6.4 Summary Predicted Mean Air Concentrations ($\mu g/m^3$) - 1985-1999 Time Period

Analyte	Exposure Area	Number of Grids	Mean Prediction	Maximum Prediction	EPC Best Estimate	EPC Upper Bound
Arsenic	Belledune	14	0.004	0.013	0.004	0.008
	Lower Belledune	23	0.013	0.029	0.013	0.058
	Petit-Rocher	4	6.10×10^{-4}	6.90×10^{-4}	6.10×10^{-4}	0.001
	Pointe-Verte	7	0.004	0.007	0.004	0.008
	Townsite	16	0.016	0.02	0.016	0.04
Cadmium	Belledune	14	0.004	0.012	0.004	0.007
	Lower Belledune	23	0.012	0.027	0.012	0.053
	Petit-Rocher	4	4.20×10^{-4}	4.90×10^{-4}	4.20×10^{-4}	8.50×10^{-4}
	Pointe-Verte	7	0.003	0.006	0.003	0.006
	Townsite	16	0.014	0.016	0.014	0.033
Lead	Belledune	14	0.131	0.434	0.131	0.262
	Lower Belledune	23	0.442	0.95	0.442	1.9
	Petit-Rocher	4	0.016	0.019	0.016	0.033
	Pointe-Verte	7	0.115	0.232	0.115	0.231
	Townsite	16	0.502	0.592	0.502	1.184

Table B6.5 Summary Predicted Mean Air Concentrations ($\mu g/m^3$) - 1975-1984 Time Period

Analyte	Exposure Area	Number of Grids	Mean Prediction	Maximum Prediction	EPC Best Estimate	EPC Upper Bound
Arsenic	Belledune	14	0.008	0.025	0.008	0.015
	Lower Belledune	23	0.025	0.055	0.025	0.11
	Petit-Rocher	4	0.001	0.001	0.001	0.002
	Pointe-Verte	7	0.007	0.014	0.007	0.014
	Townsite	16	0.03	0.037	0.03	0.073
Cadmium	Belledune	14	0.005	0.016	0.005	0.01
	Lower Belledune	23	0.017	0.037	0.017	0.074
	Petit-Rocher	4	5.90×10^{-4}	6.80×10^{-4}	5.90×10^{-4}	0.001
	Pointe-Verte	7	0.004	0.009	0.004	0.009
	Townsite	16	0.019	0.023	0.019	0.045
Lead	Belledune	14	0.294	0.975	0.294	0.588
	Lower Belledune	23	0.992	2.133	0.992	4.267
	Petit-Rocher	4	0.037	0.043	0.037	0.074
	Pointe-Verte	7	0.259	0.52	0.259	0.518
	Townsite	16	1.123	1.319	1.123	2.639

Table B6.6 Summary Predicted Mean Air Concentrations ($\mu g/m^3$) - 1967-1974 Time Period

Analyte	Exposure Area	Number of Grids	Mean Prediction	Maximum Prediction	EPC Best Estimate	EPC Upper Bound
Arsenic	Belledune	14	0.051	0.166	0.051	0.103
	Lower Belledune	23	0.17	0.365	0.17	0.729
	Petit-Rocher	4	0.008	0.009	0.008	0.015
	Pointe-Verte	7	0.048	0.092	0.048	0.096
	Townsite	16	0.201	0.242	0.201	0.483
Cadmium	Belledune	14	0.012	0.04	0.012	0.024
	Lower Belledune	23	0.041	0.089	0.041	0.179
	Petit-Rocher	4	0.001	0.002	0.001	0.003
	Pointe-Verte	7	0.01	0.021	0.01	0.02
	Townsite	16	0.046	0.054	0.046	0.109
Lead	Belledune	14	1.359	4.505	1.359	2.718
	Lower Belledune	23	4.585	9.861	4.585	19.72
	Petit-Rocher	4	0.17	0.197	0.17	0.34
	Pointe-Verte	7	1.196	2.404	1.196	2.392
	Townsite	16	5.189	6.096	5.189	12.19

Figure B6.2 Predicted Annual Average Lead Concentration ($\mu g/m^3$) Data Points – Current Time Period

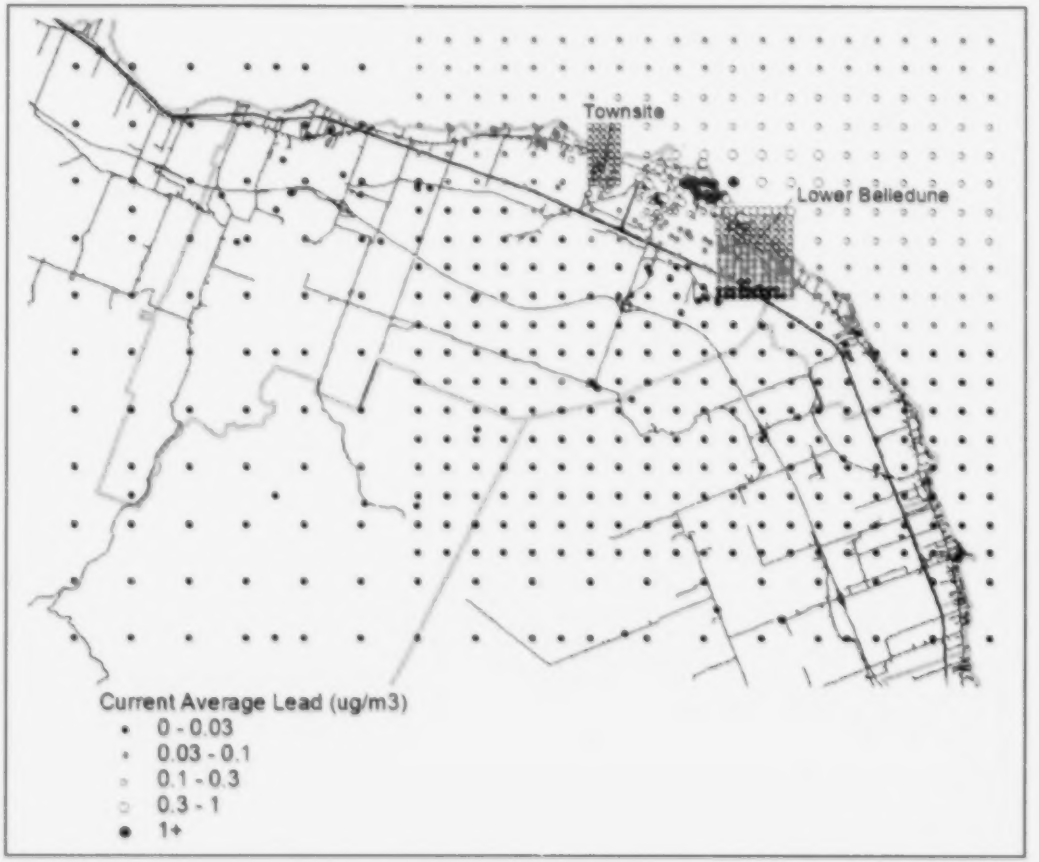


Figure B6.3 Predicted Annual Average Lead Concentration ($\mu g/m^3$) Isopleths – Current Time Period

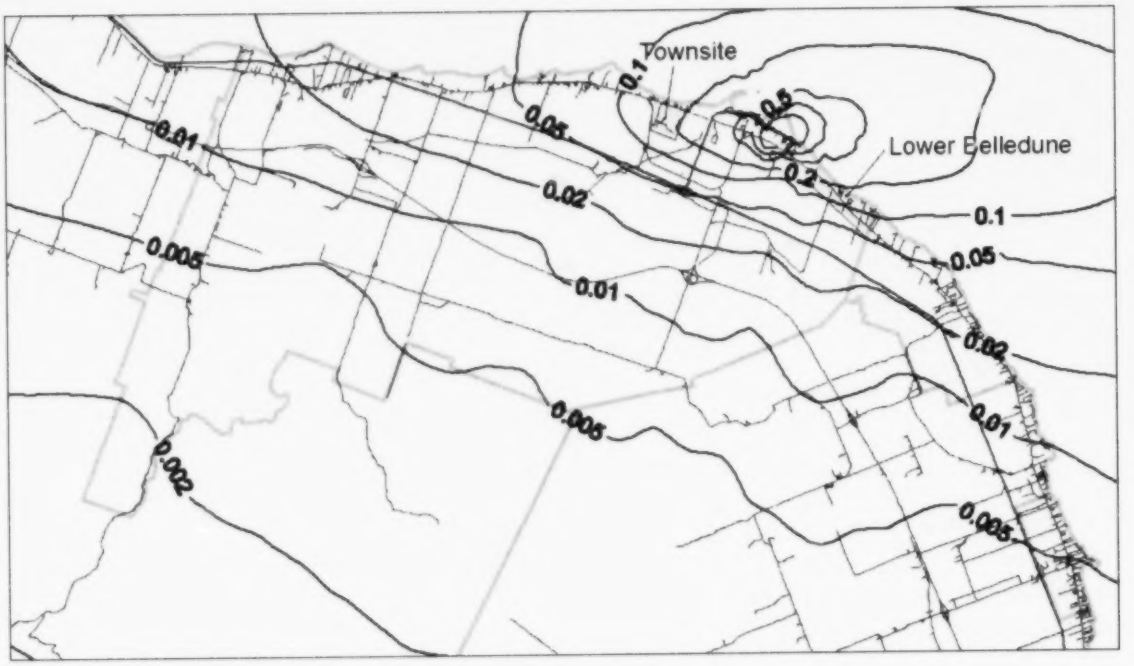


Figure B6.4 Predicted Annual Average Arsenic Concentration ($\mu g/m^3$) Isopleths – Current Time Period

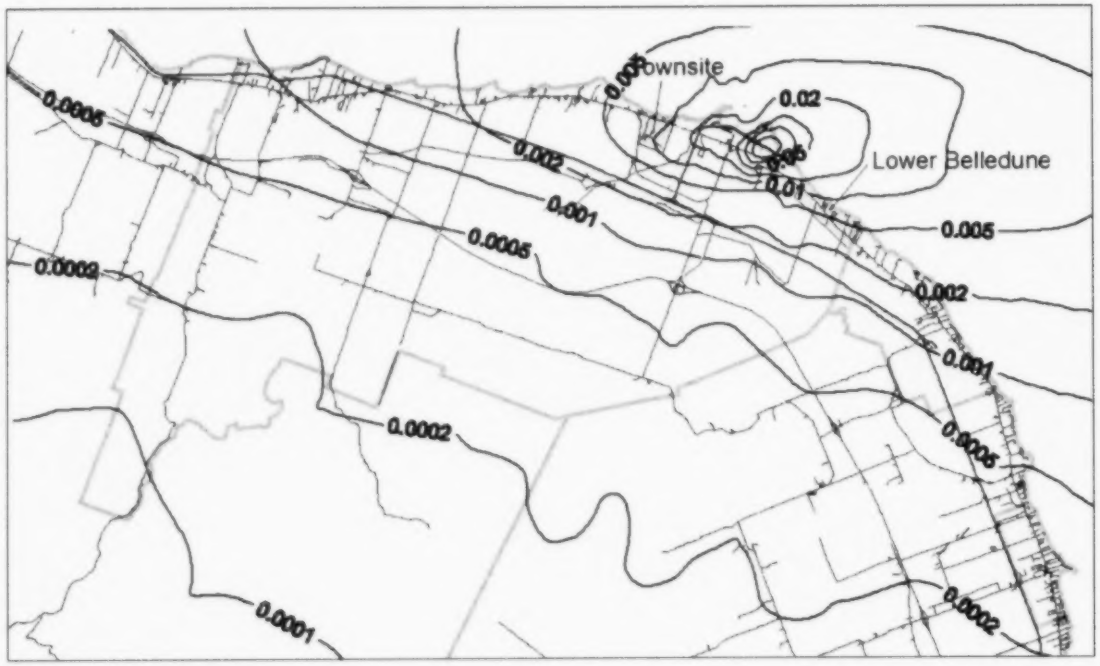


Figure B6.5 Predicted Annual Average Cadmium Concentration ($\mu g/m^3$) Isopleths – Current Time Period

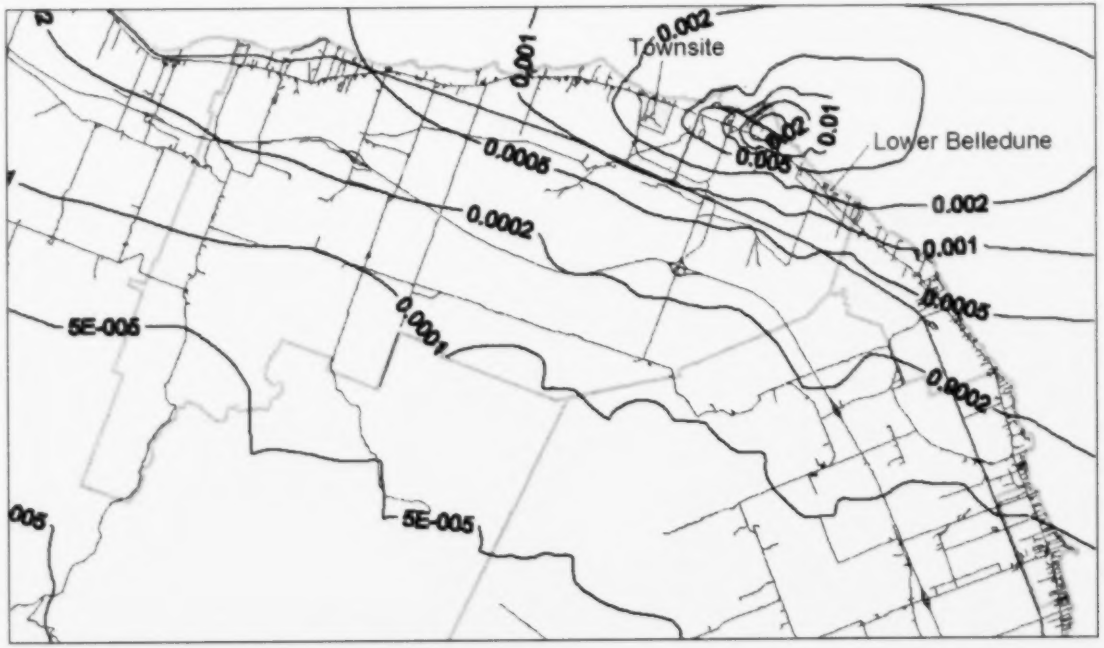
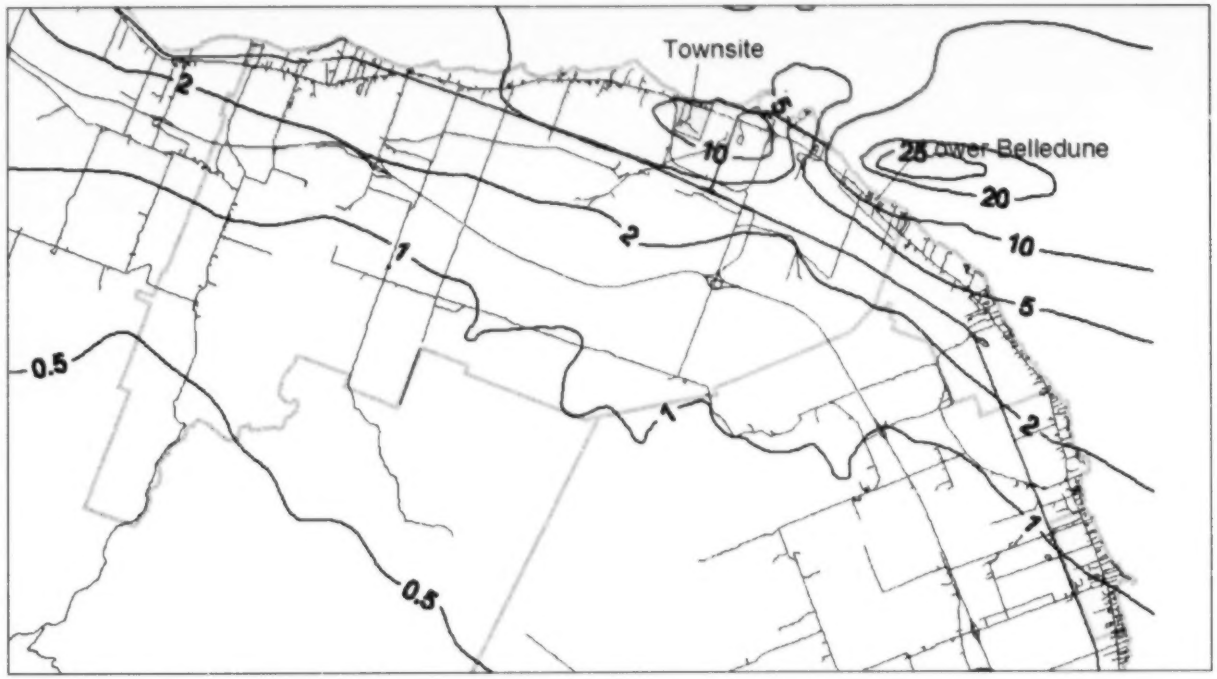


Figure B6.6 Predicted Annual Average Sulphur Dioxide Concentration ($\mu g/m^3$) Isopleths – Current Time Period



B6.5 Uncertainty And Data Gaps

For time periods when monitoring data is available, the uncertainty in the air dispersion modeling was quantified through statistical comparisons of dispersion modeling with actual data. Adjustments were made to the model predictions to better agree with the monitoring data.

The uncertainty in emission rates for the earlier time frames is likely higher than the uncertainty in the unit air concentration factors developed for this analysis. This introduces some uncertainty in the estimates for risks from carcinogens; however, the relationship to soil concentrations is less sensitive to this uncertainty.

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